



Hydrogeological Tools for Characterizing GW/SW Interactions: GW Discharge and Flow

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United States
Environmental Protection
Agency

24th NARPM Training Program

Objective of Presentation

- ◆ Provide you with an overview of techniques to investigate GW discharges to SW
 - Large-scale, rapid reconnaissance methods
 - Cost effective, small-scale, point measurement methods
 - Advantages and disadvantages of each method

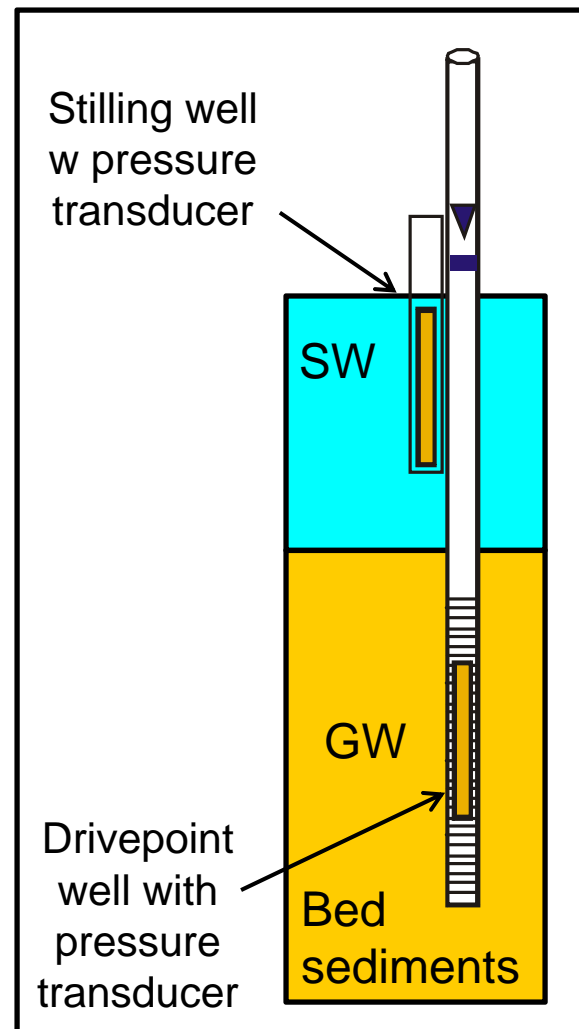
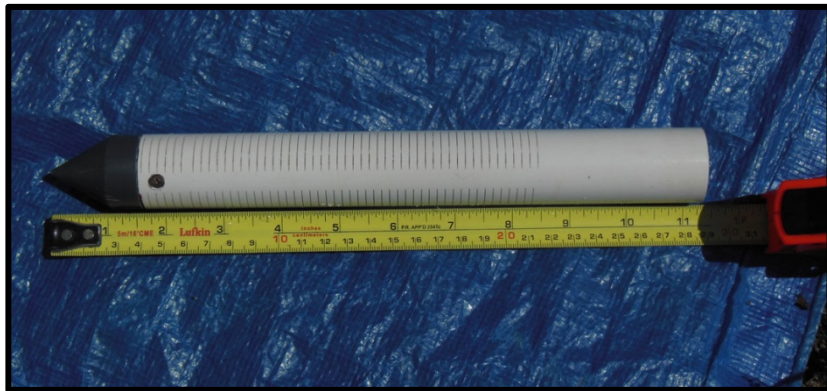
Monitoring Goals and Objectives for a GW/SW investigation

1. Understand the fate, transport and distribution of contaminants (GW, SW, and Transition Zone)
2. Collect representative samples & know their context
3. Concentrations (**exposures**) & fluxes (**loading**)
4. Find “hot spots” and “hot moments” of contaminants
5. Develop a robust and predictive conceptual model
6. Provide information for Eco Risk Assessment

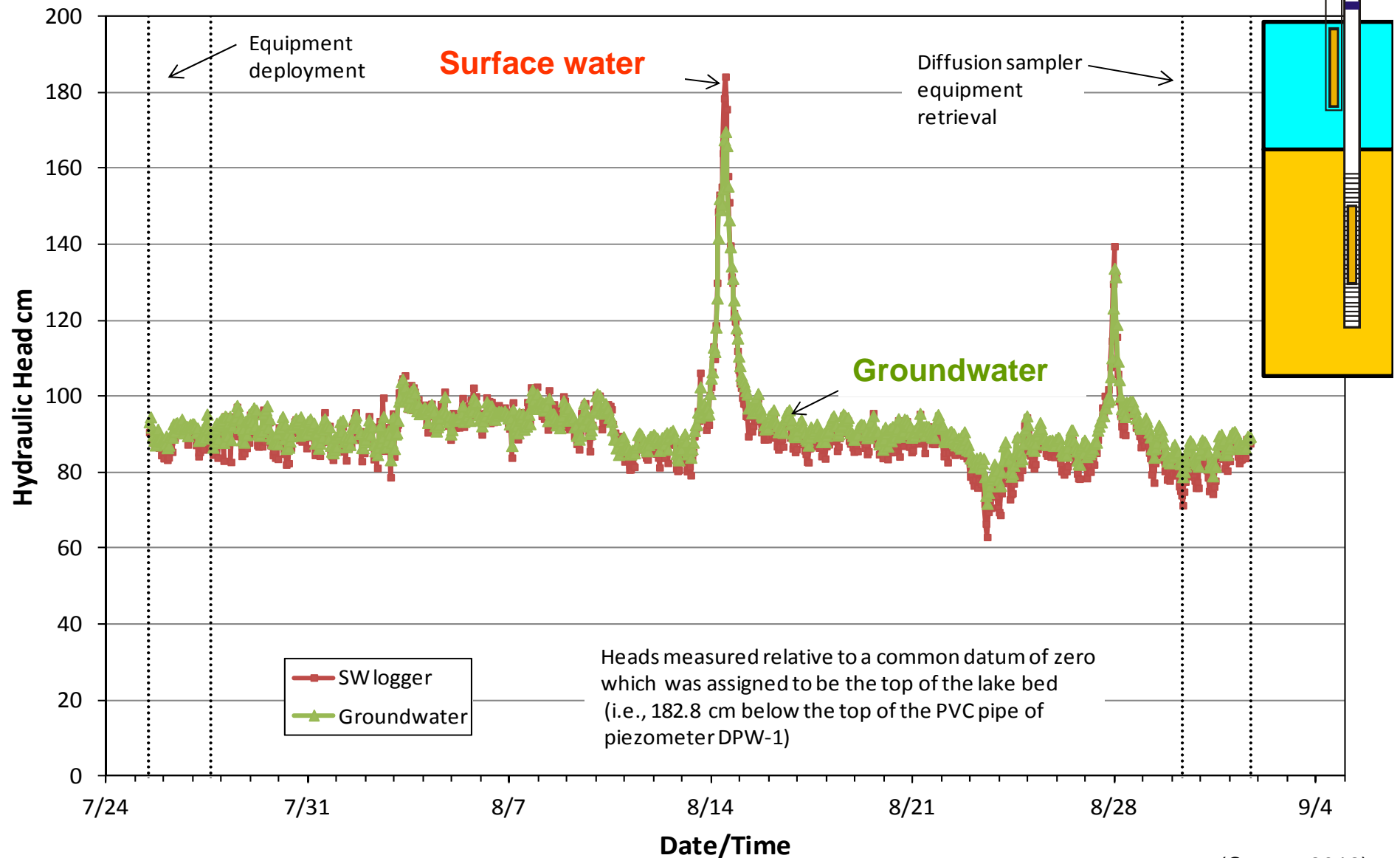
Water Level / Hydraulic Gradient Measurements

Always measure GW and SW levels to:

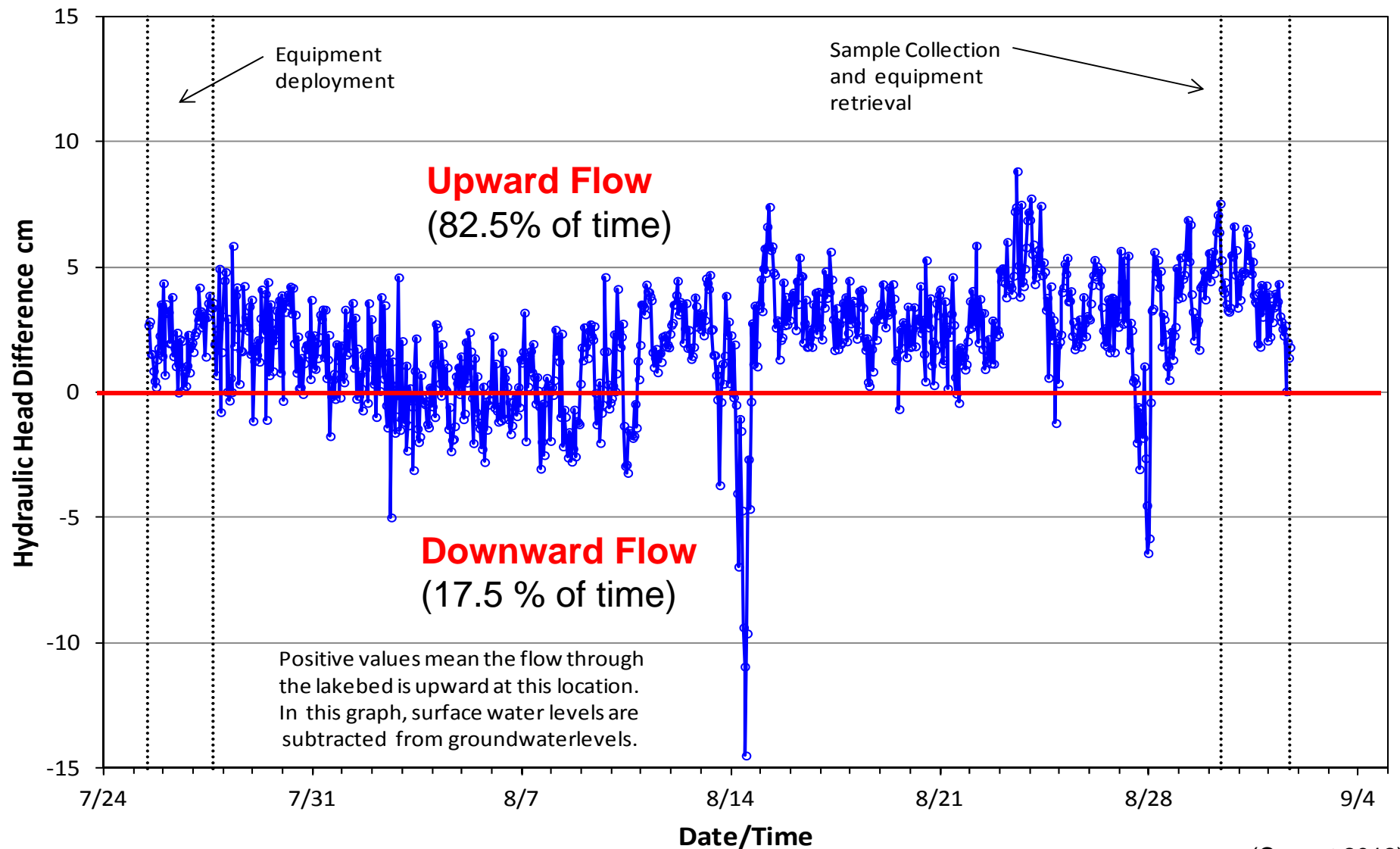
- Document dynamics
- Determine flow directions
- Plan sampling events
- Interpret other results



SW and GW Levels In Lake Michigan for Diffusion Sampler Investigations



Hydraulic Head Difference: Upward or Downward Flow in Lakebed



(Conant 2012)

Water Level / Hydraulic Gradient Measurements

Advantages

- Relatively simple to build and install
- Determines if gaining or losing without having to survey
- Provides temporal information
- Simple data interpretation

Disadvantages

- Subject to damage (vandalism, floating debris and ice)
- SW over topping top of piezometer
- Need to retrieve loggers to download



Alternate
underwater
design

GW/SW Investigation Approach for Flow

■ Multi-Method / Multi-Scale Approach

Temperature Based Recon Methods

1. Infrared (TIR) aerial surveys
2. Drag probe survey (includes WQ)
3. Lake/Stream bed temperature mapping

**Large-Scale, Large Area
Rapid Reconnaissance**



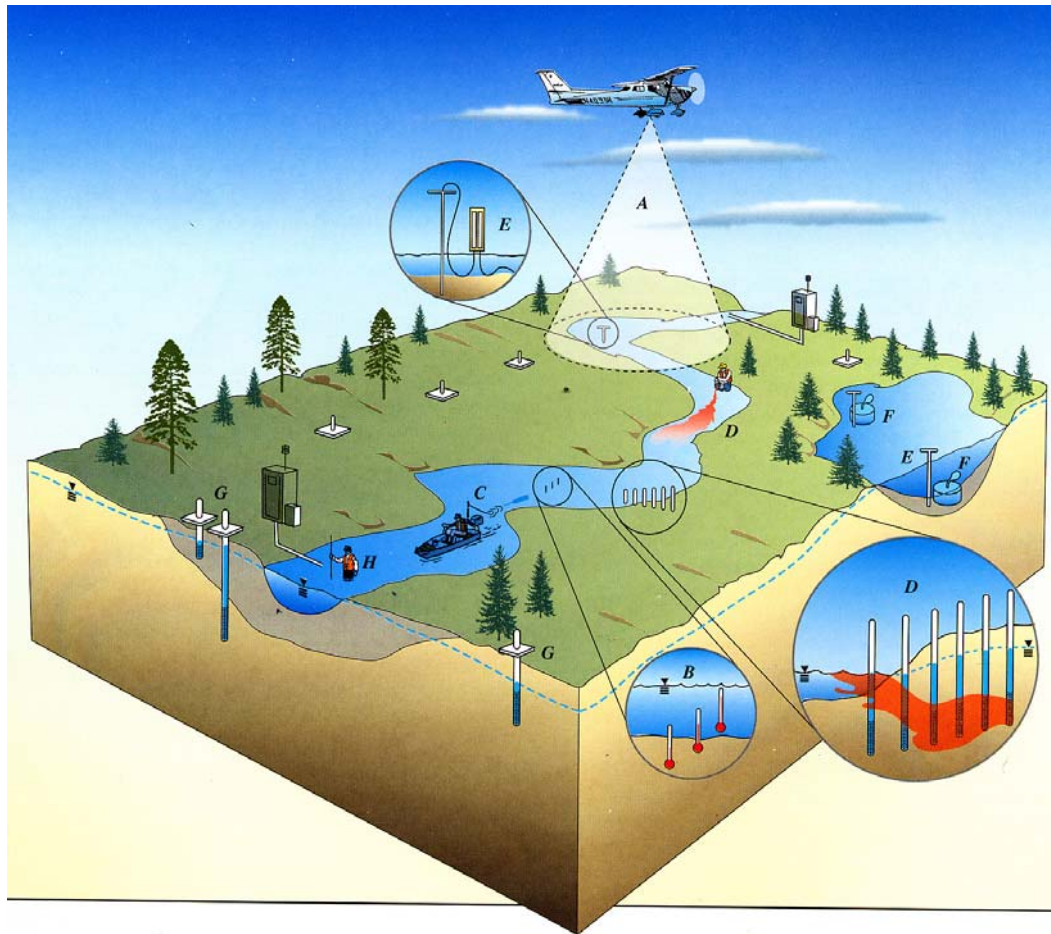
Conventional /Point Methods

4. Water level measurements
5. Mini-piezometers
6. Seepage meters

**Small-Scale
Point Measurements**

* **Note:** Geophysical reconnaissance methods will be discussed later by Briggs

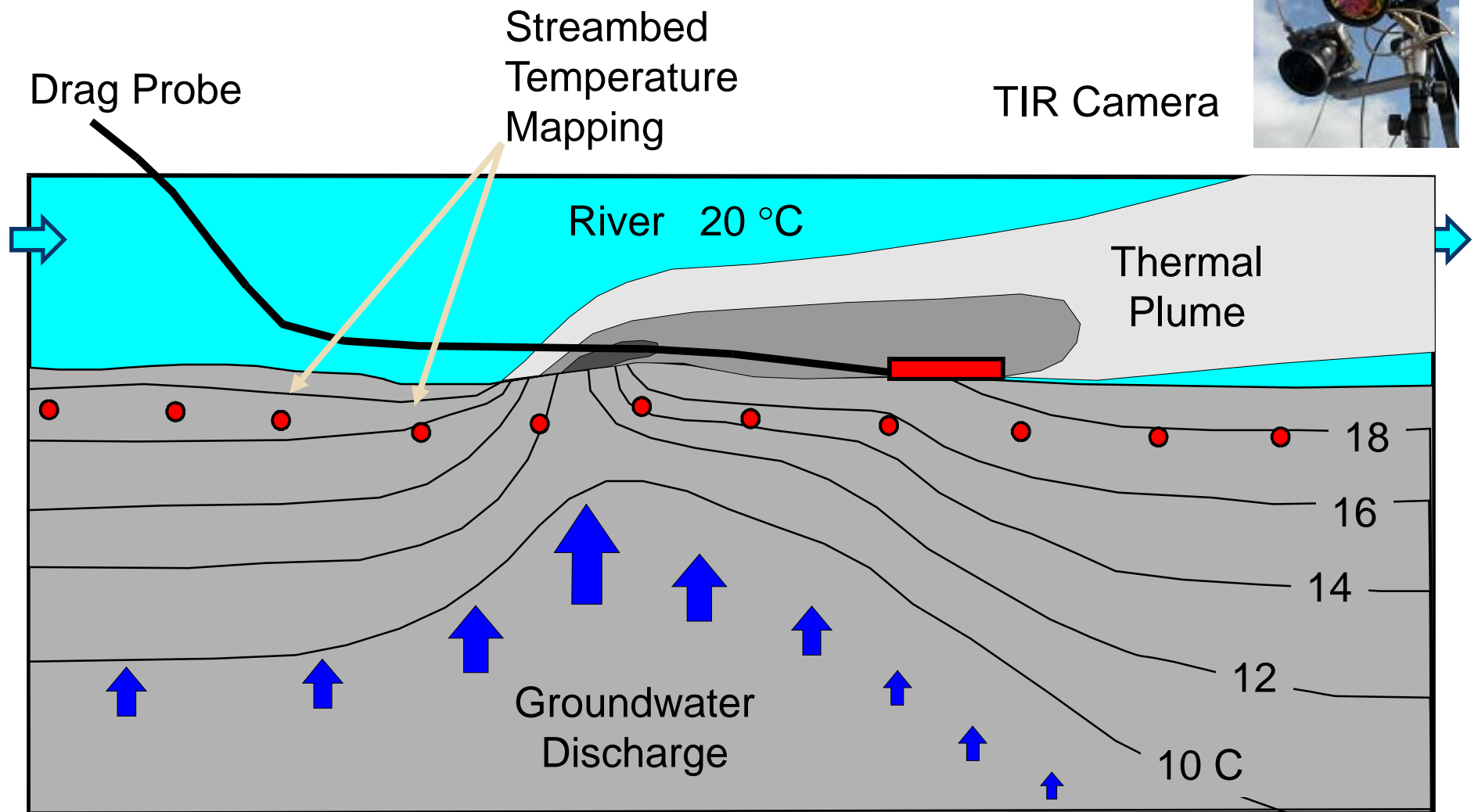
GW/SW Flux Measurement Techniques



- A. Aerial infrared imagery
- B. Thermal profiling
- C. Drag probes
- D. Dye and/or tracer tests
- E. Potentiometers
- F. Seepage meters
- G. GW flow monitoring
- H. Stream flow gauging

From **USGS Techniques and Methods Paper 4-D2**
(Rosenberry and LaBaugh, 2008)

Temperature as a Tracer: Methods



Main Limitation of all methods - need contrast in temperatures (>5°C recommended)

Temperature Methods



Heat as a tool for studying the movement of ground water near streams



Circular 1260

Stonestrom and Constantz (Eds)
USGS Circular 1260 (2003)

U.S. Department of the Interior
U.S. Geological Survey

ground
water

Anderson, M.P., 2005. Heat as a ground water tracer. *Ground Water*, v. 43, no. 6, p. 951-968

Review Paper/

Heat as a Ground Water Tracer

by Mary P. Anderson¹

Abstract

Heat carried by ground water serves as a tracer to identify surface water infiltration, flow through fractures, and flow patterns in ground water basins. Temperature measurements can be analyzed for recharge and discharge rates, the effects of surface warming, interchange with surface water, hydraulic conductivity of streambed sediments, and basin-scale permeability. Temperature data are also used in formal solutions of the inverse problem to estimate ground water flow and hydraulic conductivity. The fundamentals of using heat as a ground water tracer were published in the 1960s, but recent work has significantly expanded the application to a variety of hydrogeological settings. In recent work, temperature is used to delineate flows in the hyporheic zone, estimate submarine ground water discharge and depth to the salt-water interface, and in parameter estimation with coupled ground water and heat-flow models. While short reviews of selected work on heat as a ground water tracer can be found in a number of research papers, there is no critical synthesis of the larger body of work found in the hydrogeological literature. The purpose of this review paper is to fill that void and to show that ground water temperature data and associated analytical tools are currently underused and have not yet realized their full potential.



WATER RESOURCES RESEARCH, VOL. 44, W00D10, doi:10.1029/2008WR006996, 2008

Heat as a tracer to determine streambed water exchanges

Jim Constantz¹

Received 13 March 2008; revised 1 August 2008; accepted 18 August 2008; published 2 December 2008.

[1] This work reviews the use of heat as a tracer of shallow groundwater movement and describes current temperature-based approaches for estimating streambed water exchanges. Four common hydrologic conditions in stream channels are graphically depicted with the expected underlying streambed thermal responses, and techniques are

Constantz, J. (2008), Heat as a tracer to determine streambed water exchanges, *Water Resources Research*, 44, W00D10, doi:10.1029/2008WR006996.

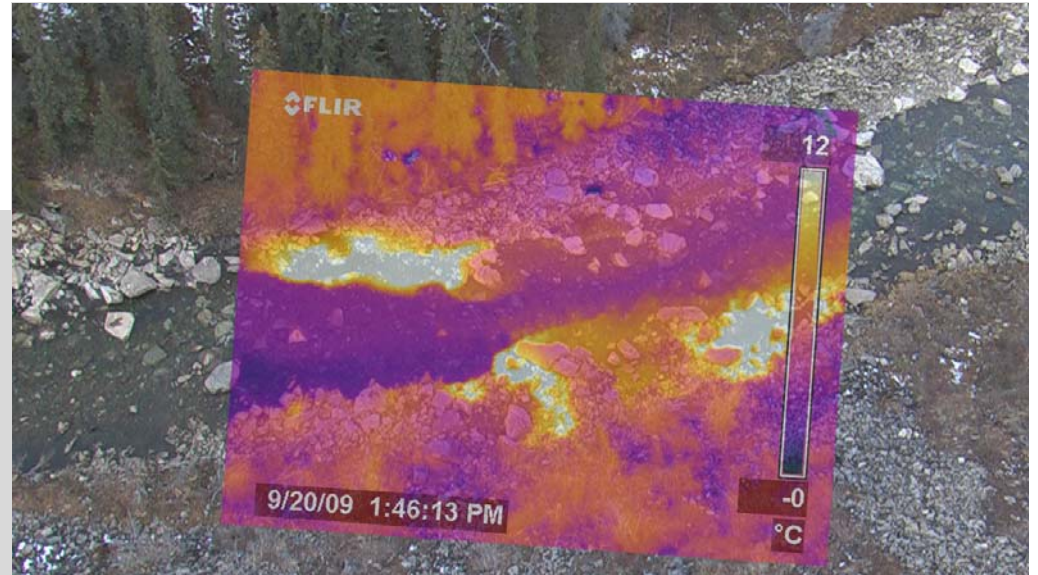
TIR Thermography

Advantages

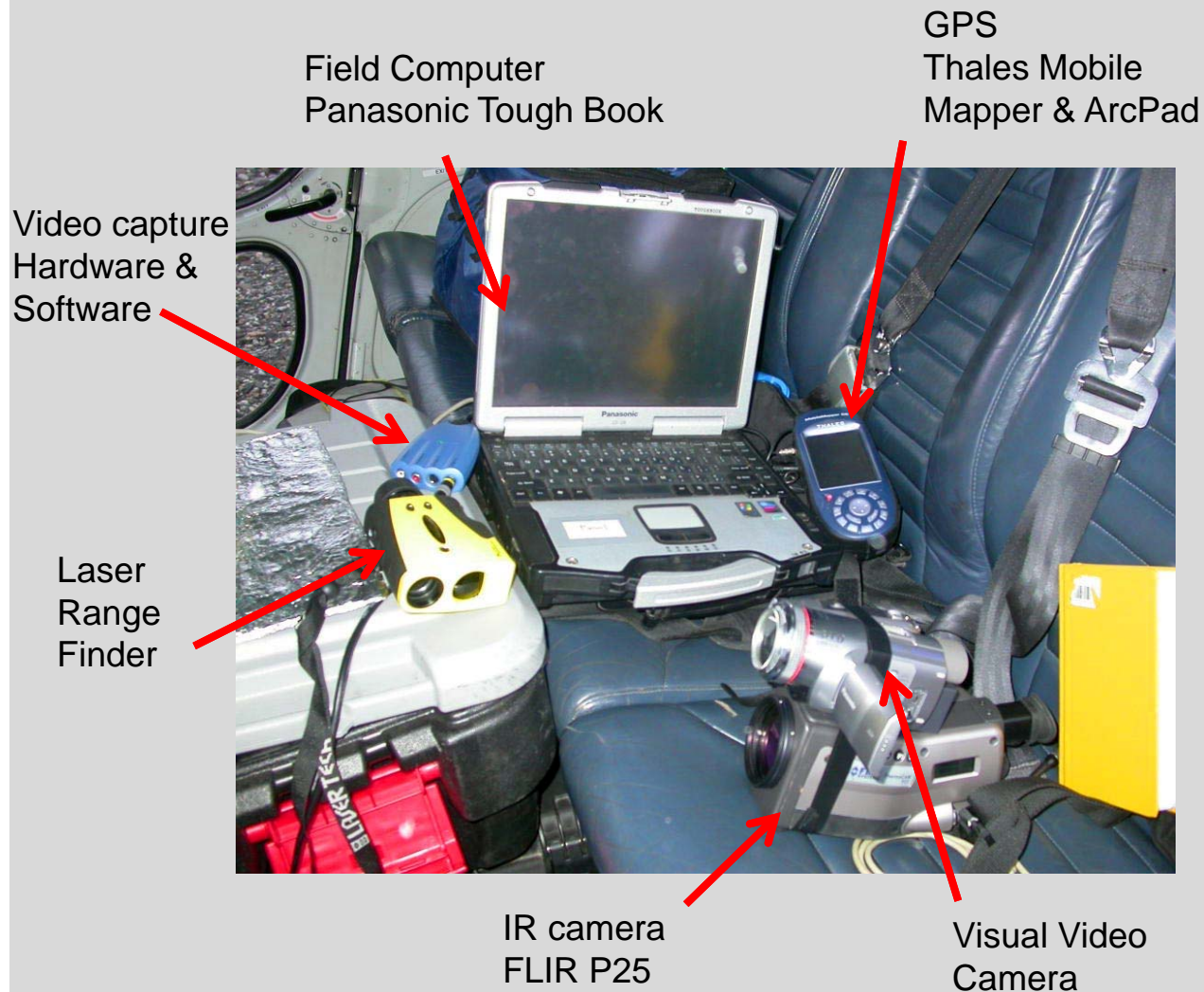
- Large spatial coverage
- Quick acquisition times
- Real-time data interpretation
- Won't miss largest anomalies

Disadvantages

- Surface measurement only
- Timing and environmental conditions are important
- Distinguishing spatial from temporal variations
- Complications from reflected images
- GPS position not exactly same as for photo

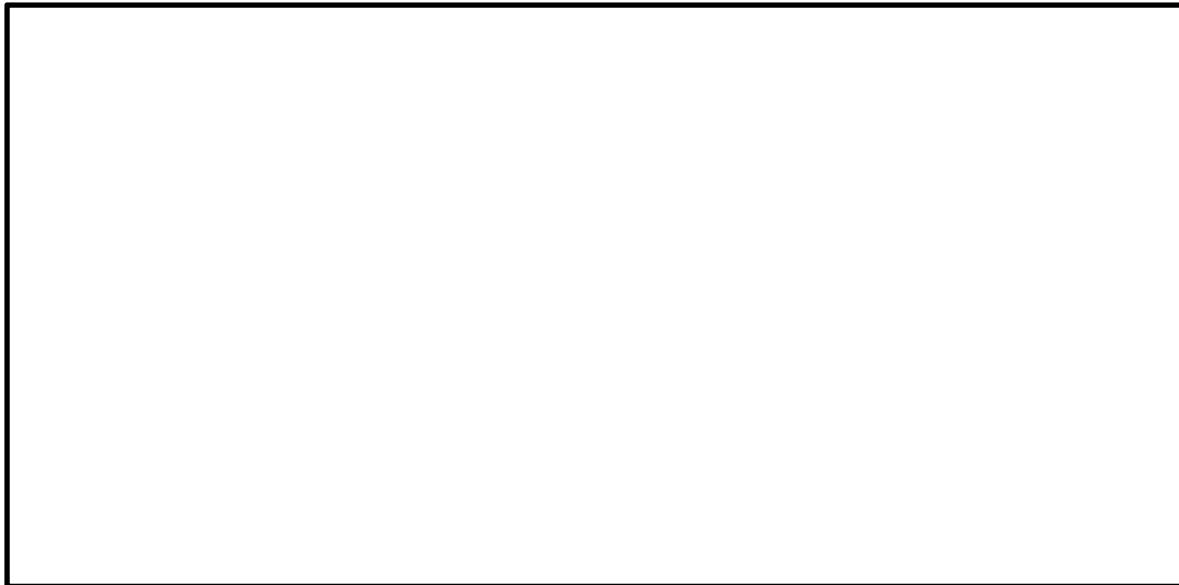
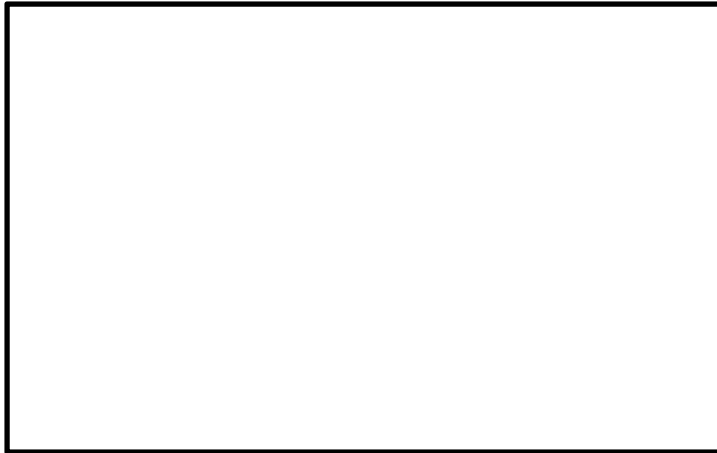


TIR Thermography System



Photos from N. Utting

Grand River Ontario, Canada Summer Survey



Timing of IR Survey is Important



Winter



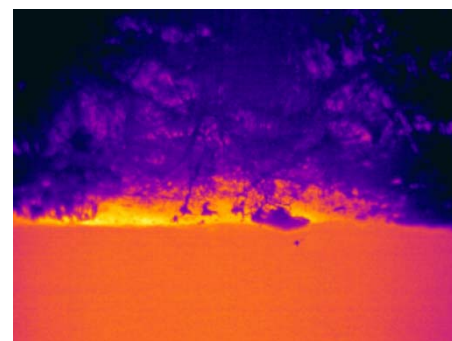
Summer (6:40 – 11:15 AM)

(Tateishi 2016)

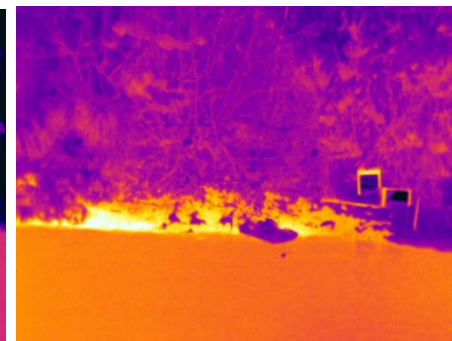
Coolest



Warmest



7:44 AM

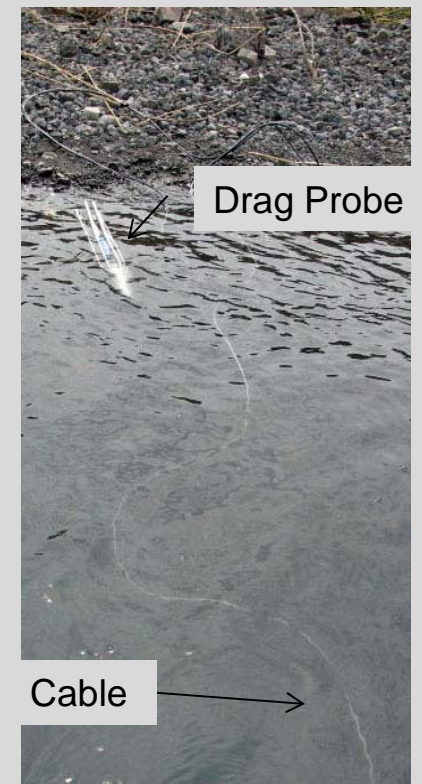
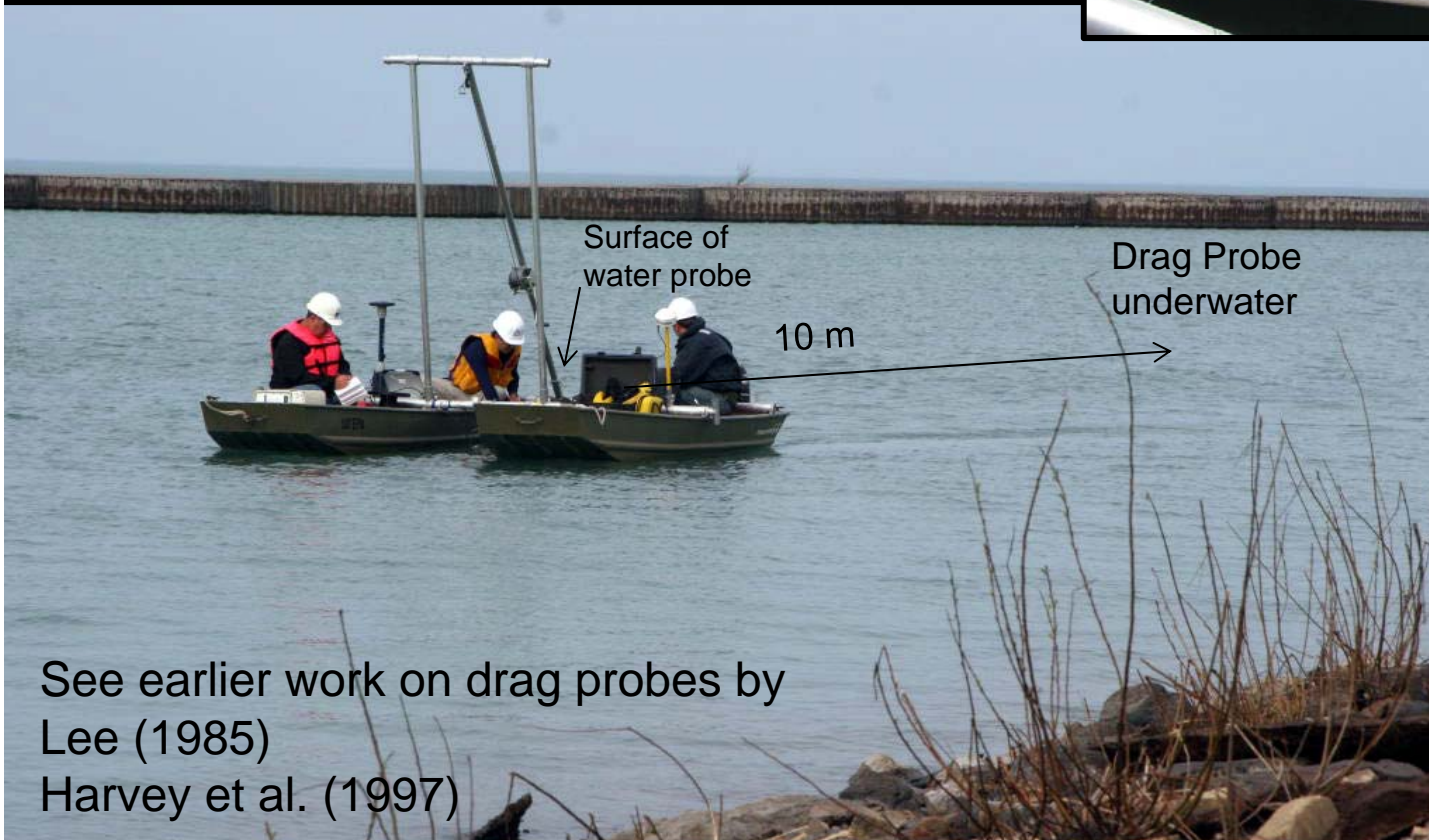


10:59 AM

Winter (7:44 – 10:59 AM)

(Tateishi 2016)

Drag Probe (Insitu – Troll 9500)

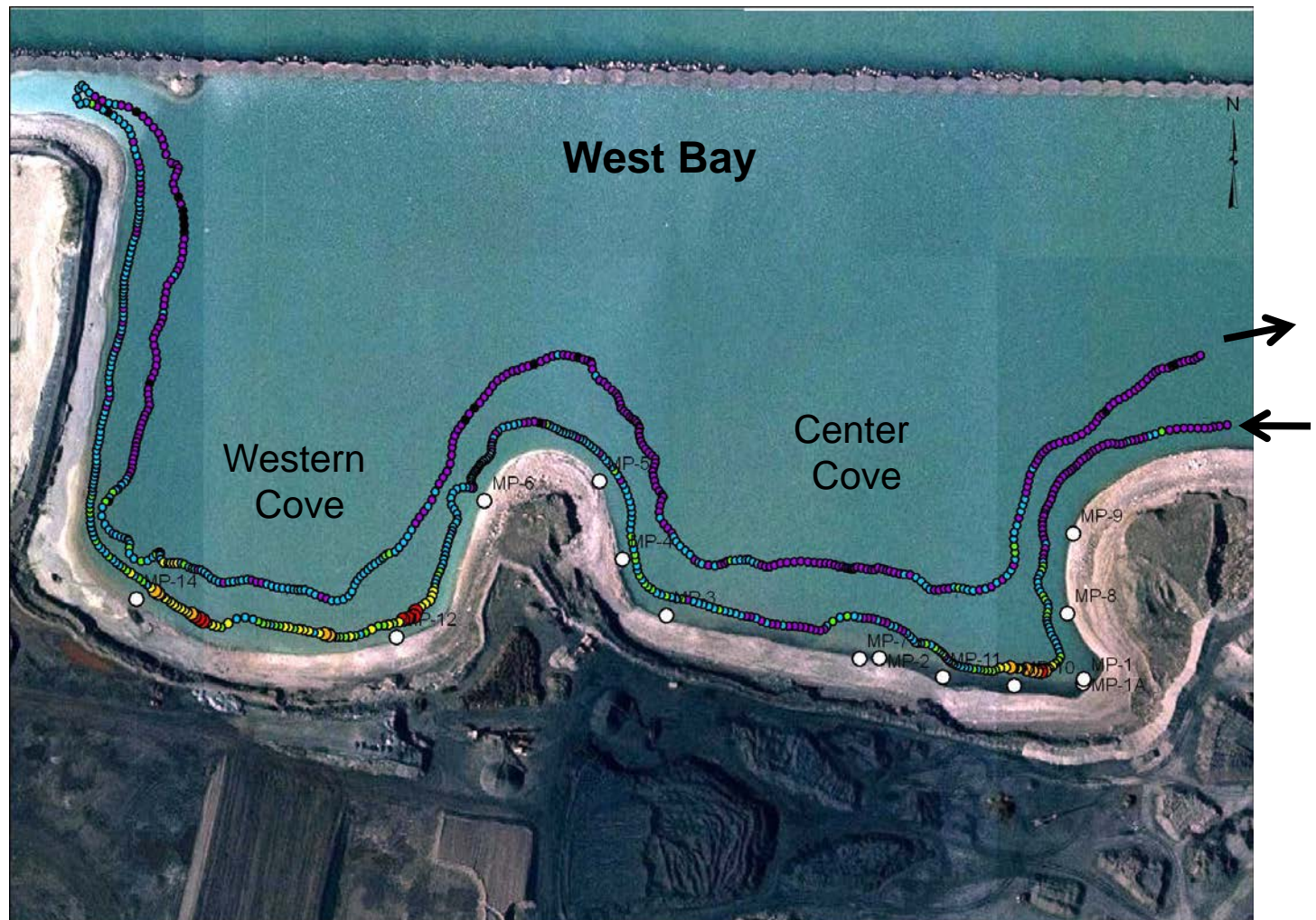


Specific Conductance - Drag Probe Traverse 2

Specific Conductance
uS/cm (at 25 C)

- < 280
- 280 - 290
- 290 - 300
- 300 - 320
- 320 - 360
- 360 - 440
- 440 - 600
- > 600

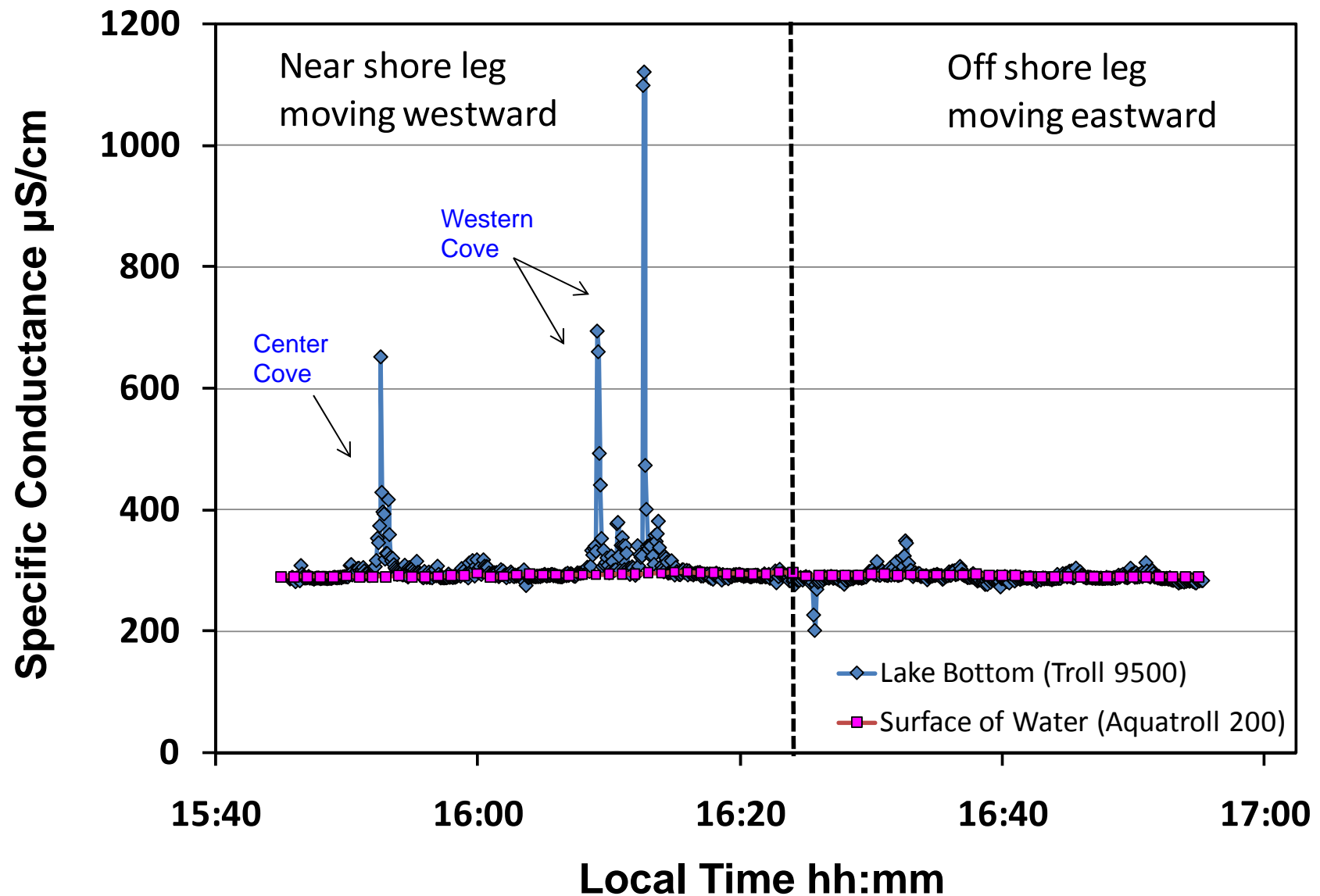
SC better than
temperature in
this survey



0 50 100 200 Meter

(Conant 2010)

Specific Conductance - Drag Probe Traverse 2



(Conant 2010)

Drag Probe Survey

Advantages

- Can measure WQ (SC, pH, Eh, DO, turbidity) and Temp
- Sensitive to GW discharges at sediment/water interface
- Traverses can cover several kilometers in day
- Specific conductance can be useful when temperature isn't

Disadvantages

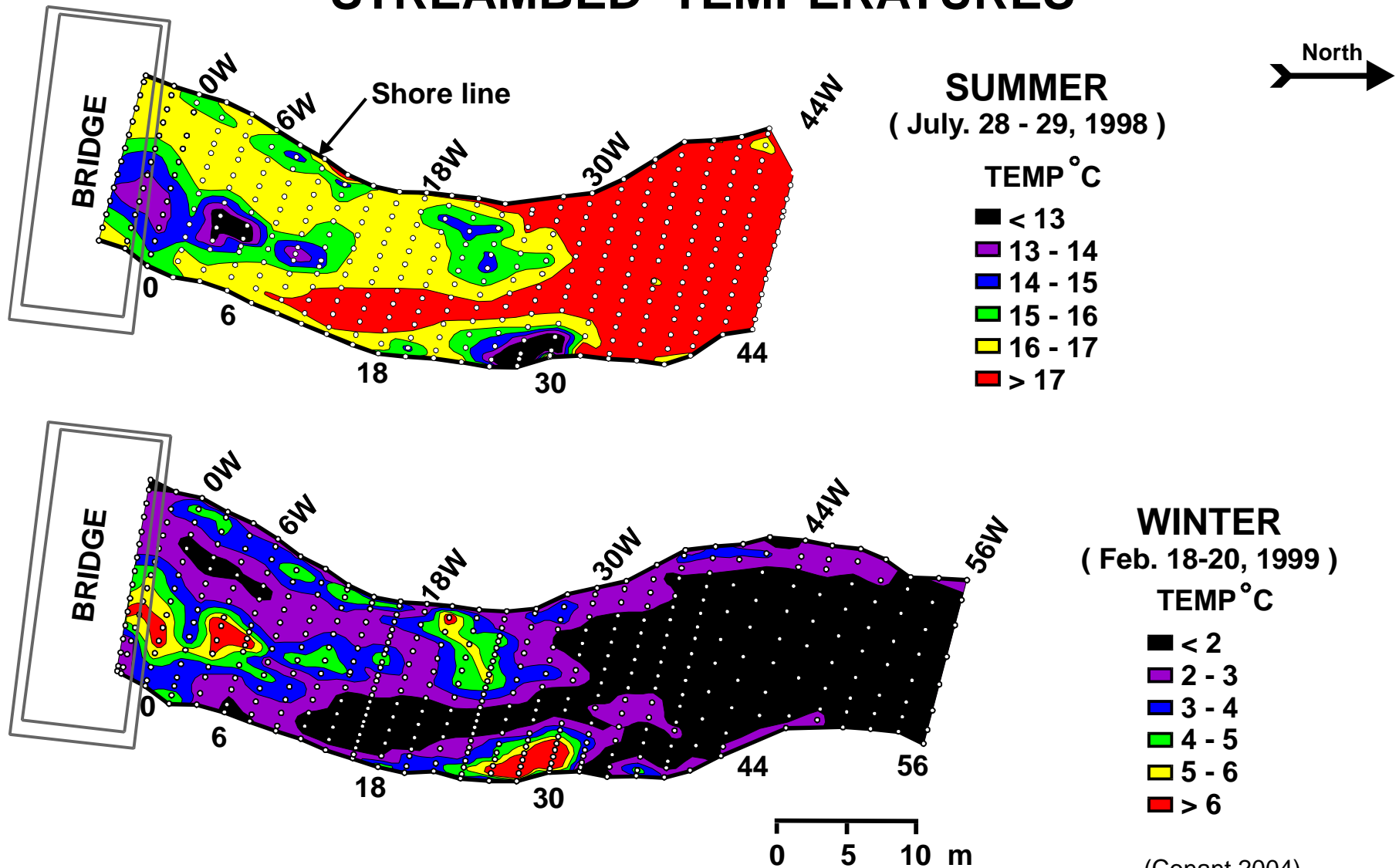
- GW discharges must be large enough to change SW quality
- Potential for probe to snag & be damaged
- As boat speeds increase – method sensitivity decreases
- GPS position not exactly same as probe
- Beware of SW discharges (e.g., storm drain outfalls)



Sediment Bed Temperature Mapping



STREAMBED TEMPERATURES



(Conant 2004)

Sediment Bed Temperature Survey

Advantages

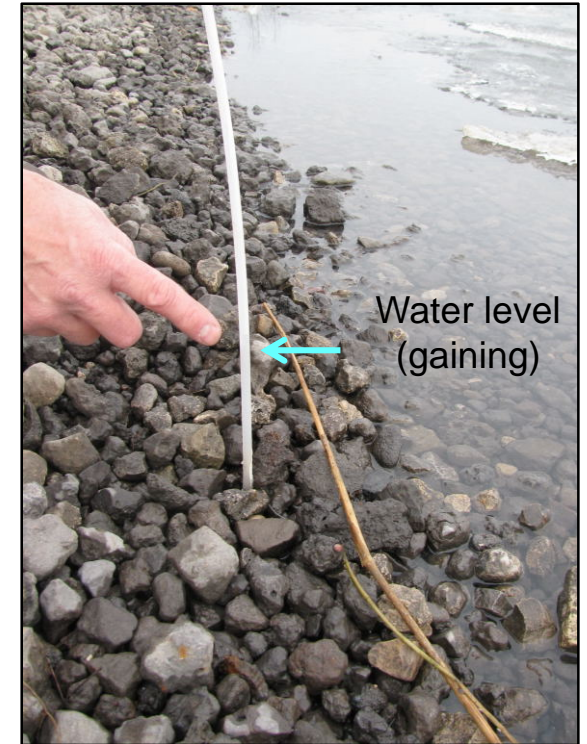
- Sensitive to lower GW discharge fluxes
- Can be immediately interpreted
- Can quantify GW *discharge* fluxes
(Conant 2004, Schmidt et al. 2007)

Disadvantages

- Need relatively constant GW and SW
- Must physically insert probe
- Probe equilibration times (2 to 10 min)
- Slower data collection (50 to 100 /day)
- Surveying locations



Mini-piezometers



To determine vertical flow directions

See Lee and Cherry (1978) for a “how-to” description

Measuring Water Level Differences



Photo from USGS Techniques and Methods Report 4-D2 (Rosenberry and LaBaugh, 2008)

A **potentiometer** can help when

- the mini-piezo WL is below SW
- wavy conditions
- WL differences are small

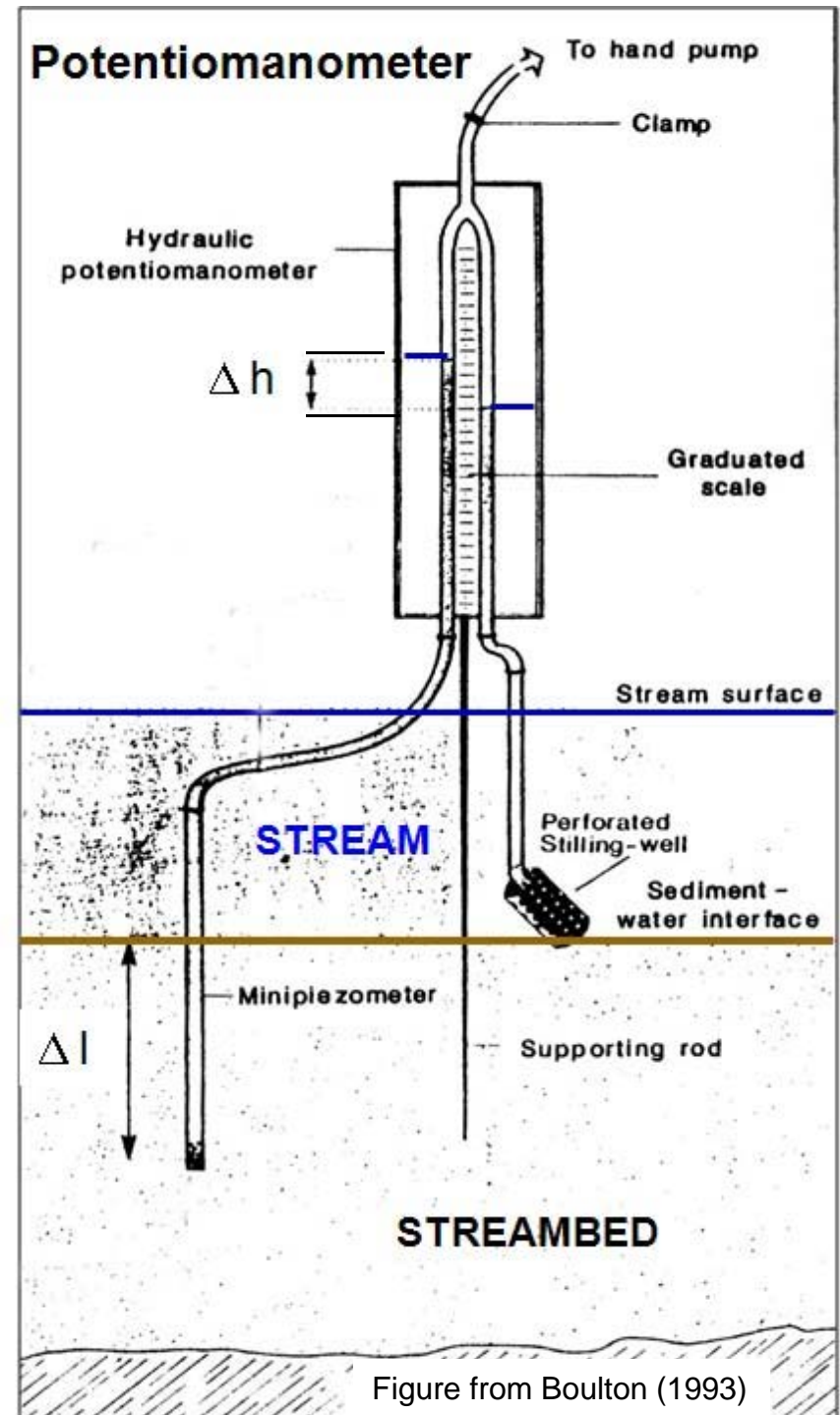


Figure from Boulton (1993)

Mini-piezometers

Advantages

- Inexpensive
- Easy to make and install
- Measures hydraulic head
- Immediately determines gaining or losing
- Can use to sample WQ
- No drill rig needed to get GW

Disadvantages

- Sometimes WL difficult to read
- Potential flow along annulus if hole does not collapse
- Non-permanent



Seepage Meters

Provide a direct measurement of flux

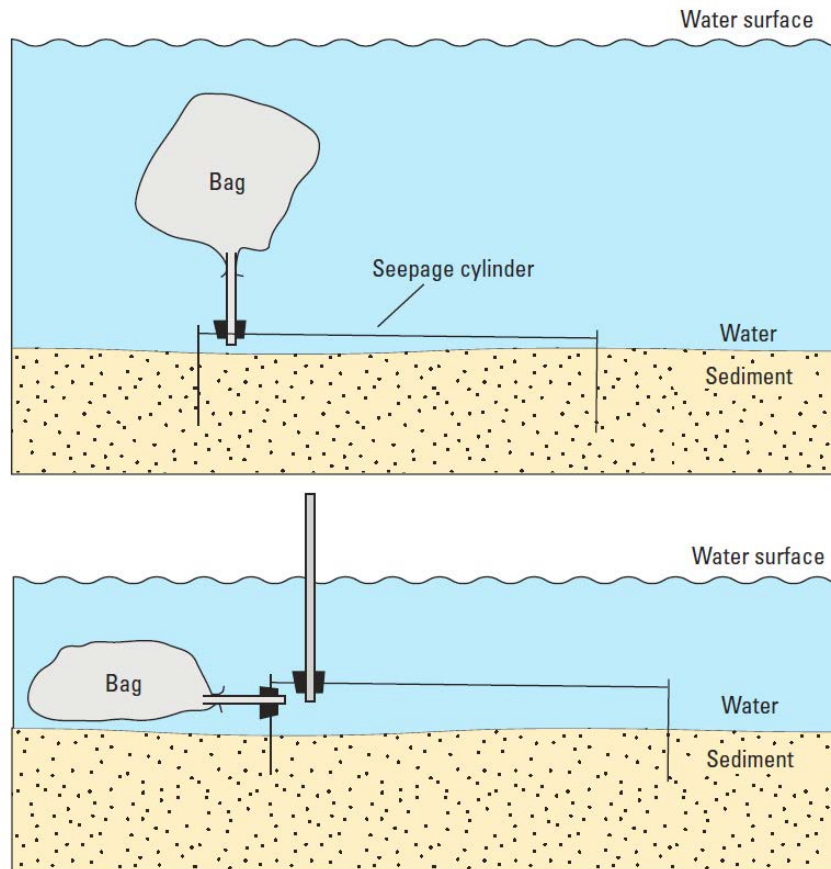


Diagram and photo from Rosenberry and LaBaugh (2008)



Flux (specific discharge)

$$q = (\Delta V/t)/A$$

Where:

q = flux in m/s

A = area of seepage meter in m^2

V = volume in m^3

t = time in seconds

Seepage Meters

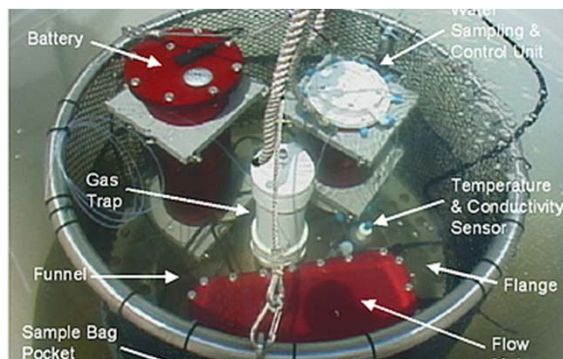
Different Types and Designs



“Classic” 55 gallon drum type (Lee and Cherry 1978)



UltraSeep Automated continuous monitoring (Chadwick et al. 2003)



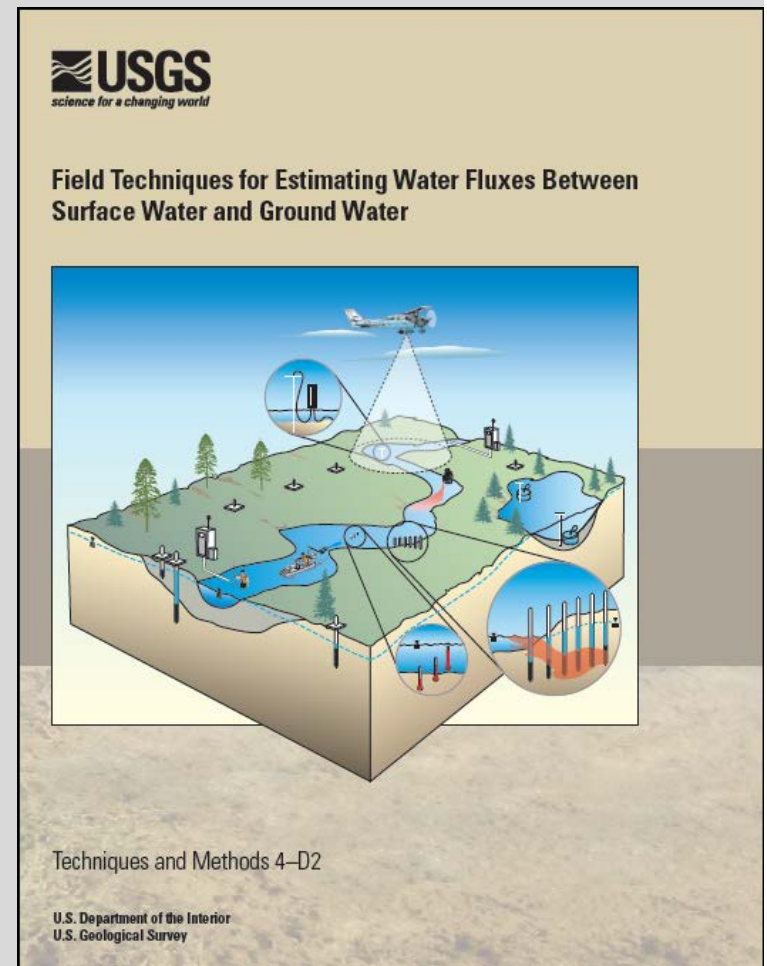
Seepage Meters

Advantages

- Easy to install (shallow)
- Direct measurements of flux
- Can calculate GW velocity and K (if have head and porosity data)
- Inexpensive to really expensive

Disadvantages

- Difficult to install when rocky
- Care needed to avoid errors
e.g., bag effects, waves
- Long deployment times
- Spatial vs. temporal variability
- Not recommended for WQ samples
- Deep deployments difficult



USGS Techniques and Methods 4-02
(Rosenberry and LaBaugh, 2008)

Some Take Home Messages

1. Measure GW and SW water levels over time
2. Temperature-as-a tracer methods are good reconnaissance tools for finding GW discharge
3. Most methods are relatively simple, cost effective and easy to interpret.
4. High GW discharge locations are *possible* plume discharge locations
5. To determine GW recharge (losing) conditions requires monitoring of hydraulic gradients or modeling temperatures

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